Four-Corner Concept: CT-Based Assessment of Fracture Patterns in Distal Radius

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Abstract

Operative treatment using plate fixation is an important adjunct in the treatment of distal radius fractures, although the evidence for its superiority over other modalities remains limited. We propose a new concept for fractures of the distal radius, based on the three-column model of the distal radius, and on the expanding knowledge about the different fracture patterns obtained by evaluation of the distal radius by computed tomographic (CT) scan. All fracture types can be characterized by subdividing the wrist joint into four corners, each with its own characteristics in terms of mobility, stability, and transfer of forces in the intact distal radius. Recognition of the specific fracture types based on this four-corner concept enables a tailored approach to treatment.

Keywords
- distal radius fractures
- intra-articular fractures

Four-Corner Concept

The four-corner concept is based on the combination of the three-column model of Rikli and Regazzoni[1] and Melone's four-part classification.[2] The radius-ulna complex can be divided into four corners, each of which has a special biomechanical function and its own behavior after injury (►**Fig. 1**). At least eight different fracture patterns can be distinguished, with and without a fracture of the ulna (►**Fig. 2**). In extra-articular fracture patterns, the radial, dorsal, and ulnar corners remain as an intact block, which is separated from the shaft, ulnar corner, or both. In partial intra-articular fractures, theoretically six different patterns can be described depending on which corner is fractured. Per definition, at least one corner remains intact and in continuity with the shaft. The radial, dorsal, or volar corner can be involved individually or in paired combinations: radial and dorsal, radial and volar, and dorsal and volar. In complete articular fractures, all articular components, that is, the radial, dorsal, and volar corner are separated from the shaft.

The **radial** corner is responsible for radiocarpal stability and is formed by the radial styloid and scaphoid fossa to which the strong volar radiocarpal ligaments are attached. In fracture dislocations, the styloid can be torn off (as an equivalent to a tear of the radiocarpal ligaments: a bony avulsion) and is displaced distally and ulnarly (avulsion type). If predominantly compression and bending forces are involved (compression type), the fragment tends to rotate into supination and displace proximally due to the attached insertion of the brachioradial muscle. Usually an intra-articular step-off is present.

The **ulnar** corner consists of either the ulnar head or ulnar styloid, and is important for distal radioulnar joint (DRUJ) stability. It is the stable pivot around which the radius rotates. Ulnar styloid fractures can be left untreated when the DRUJ is stable[3,4] but must be addressed in case of instability due to a disruption of the deep radioulnar ligament attachment. Additionally, the ulnar corner plays an important role in force transmission across the wrist joint. In vivo measurements have shown that up to 50% of forces are transmitted across the ulnar column with physiologic unloaded motion.[5]

The intermediate column that takes a large part ($>$ 50%) of the axial compressive forces that are transmitted across the wrist during normal activity[5] consists of the lunate fossa and the sigmoid notch. In the fracture setting, an axial CT scan is

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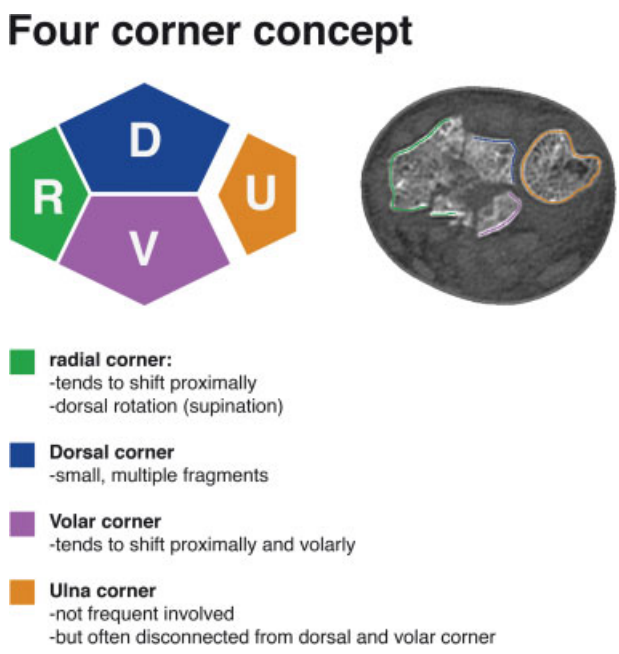

Fig. 1 An axial CT view allows four corners of the distal radius and ulna to be distinguished. The volar and dorsal corner fragments are those involving the sigmoid notch.

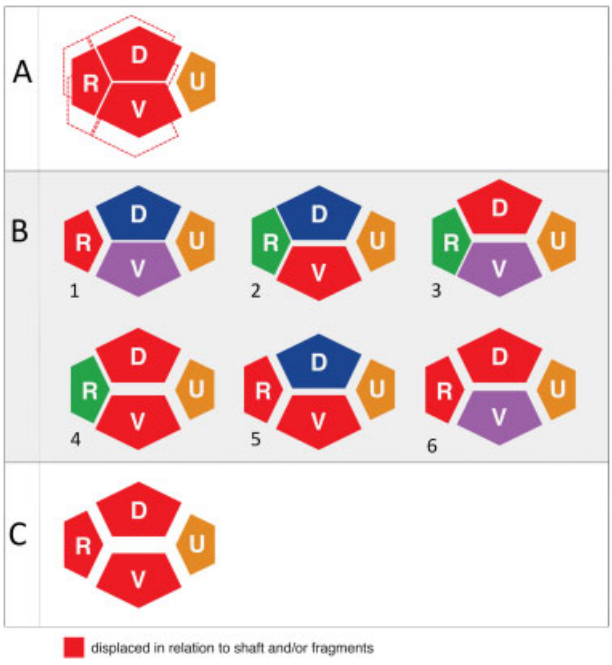

Fig. 2 A total of eight different fracture patterns of the distal radius can be distinguished. Besides extra-articular (**A**) and complete intra-articular fracture patterns (**C**), theoretically six different partial intra-articular patterns (**B**) are possible, but some will be extreme rare in clinical practice.

the best method to visualize whether there is a sagittal split of the lunate fossa into a dorsal and a volar fragment (corner).

An isolated fracture of the **dorsal** corner is seldom seen. It usually occurs in combination with a radial corner fracture and/or volar corner fracture. As part of the dorsal corner, small central articular fragments that are impacted into the metaphysis can be seen here and can only be reduced through a dorsal approach. If the dorsal corner fragment is substantial and displaced, it should be addressed specifically. A malunited dorsal corner fragment affects the congruency of the radiocarpal joint surface and of the sigmoid notch (DRUJ), and can be disastrous if not treated properly (►**Fig. 3**).

The **volar** corner, in case of a complete articular fracture, tends to rotate dorsally (extension) due to the pull of the volar radiocarpal ligaments. The volar corner has the thickest cortical bone and comminution is therefore seldom seen, but if the buttress of this fragment is lost due to cortical comminution, direct reduction and fixation are necessary. If shear fragments of the volar corner are present ("reverse Barton"), small "volar rim" fragments of the carpus tend to sublux volarly due to the strong radiocarpal ligaments.[6,7] Great care must be taken to firmly fix this fragment, especially when this fragment is small, to avoid secondary displacement with subluxation of the proximal carpal row (►**Fig. 4**). Malrotation of the volar and dorsal corner in the sagittal plane with clockwise rotation of the dorsal corner fragment and counter-clockwise rotation of the volar corner fragment can result in narrowing of the radiocarpal joint surface with clinically relevant loss of wrist flexion/extension.[8,9] The three corners of the radius actually correspond with the osseoligamentous units, described by Bain et al.[10] Based on studies in the past, fragments tend to be fixed to the ligaments, whereas the fracture lines are basically in the so-called interligamentous zones.[10] This might explain the recurrence of the specific fracture configuration.

The "Key Corner"

The four-corner concept draws attention to a clinical observation coined "the key corner": the sagittal reconstruction of the CT scan is analyzed at the level of the intermediate column; in some situations it can be demonstrated that the lunate (the proximal carpal row) goes together with a displaced either dorsal or volar corner fragment into slight subluxation. This carpal subluxation is probably more important than a step-off (without subluxation) and should be corrected to avoid chronic subluxation with alteration of the entire joint kinematics. The fragment with which the lunate goes is considered the "key corner" and its control with reduction and stable fixation should be the first step and an integral part of the operative strategy. This fragment is not necessarily the largest fragment on the CT scan (►**Fig. 5**).

Fracture Patterns

Extra-articular fractures of the distal radius can affect the DRUJ (ulnar corner in relation to the intermediate column) or the radiocarpal and midcarpal joints in case of dorsal or volar tilt.

The best way to regain full function is to restore the anatomy between the radius and ulna.[11] In (*partial*) *intra-articular fractures* the CT scan helps us assess the size and relevance of the specific corners. Small fragments could

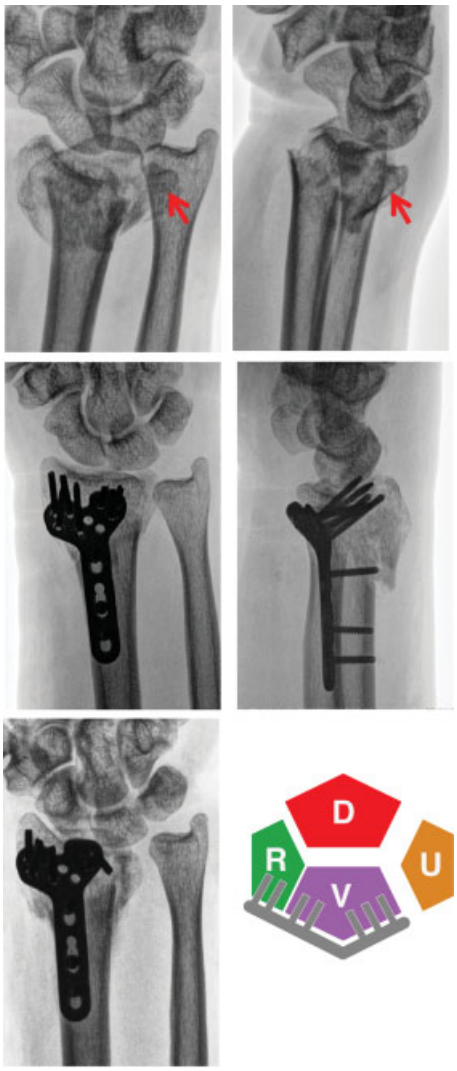

Fig. 3 Although the distal fragments were fixed with a volar plate with seven screws, the dorsal corner was not fixed, leading to an intra-articular malunion with malalignment of the DRUJ joint.

indicate radiocarpal instability, due to ligamentous avulsion, and are per definition unstable. Any displaced volar or dorsal corner in respect of the other corners and/or shaft, which is

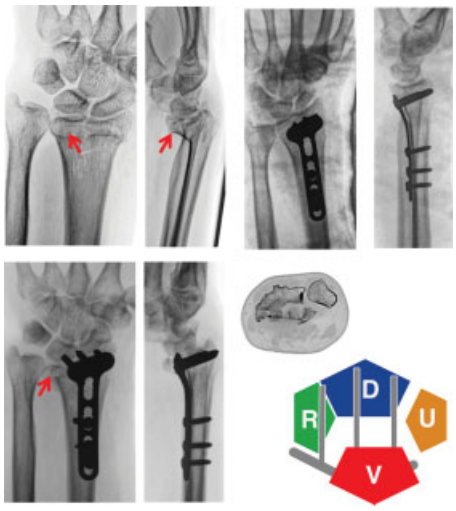

Fig. 4 In this case the volar ulnar corner was not captured with the volar T-plate, resulting in secondary displacement.

still related to the lunate bone, needs attention. When the proximal row follows the dislocated fragment of the radius resulting in a subluxation, this fragment (the key corner) should be addressed, either from the volar or the dorsal side, and needs to be reduced and fixed. It is hardly possible to reduce a dorsal key corner from the volar side and in those cases a dorsal approach is advised. A straight approach between the third and fourth extensor compartment and fixation with a fragment-specific plate under the envelope of the extensors digitorum (fourth compartment) is advocated (►**Fig. 6**). When both corners are separated, leaving the lunate in between (►**Fig. 5D**), there is no key corner, but reduction and fixation of both is mandatory to restore intra-articular anatomy (sandwich or triple plating) (►**Fig. 7**).

Recognition of the correct fracture pattern is the most important first step to identify which corners are involved and which corner needs reduction and fixation. Classification, using CT scans are more reliable than plain X-rays.[12] In general all helical CT scans with routine axial and sagittal and coronal reformatted images views with 2-mm-thick images at l- or 2-mm intervals will do. Displacement between

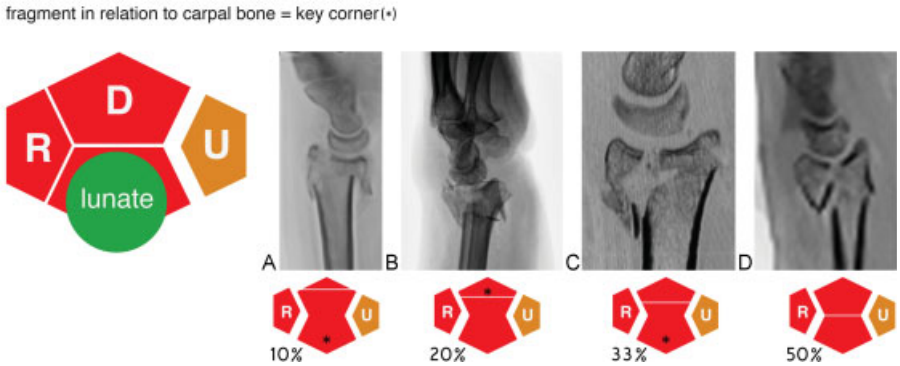

Fig. 5 Although there is a large variety in the size of the volar and dorsal corner, the fragment that is in congruency of the lunate is the key corner. ►**Fig. 5D** shows a separate volar and dorsal corner, both in contact with the lunate bone. No key corner can be distinguished.

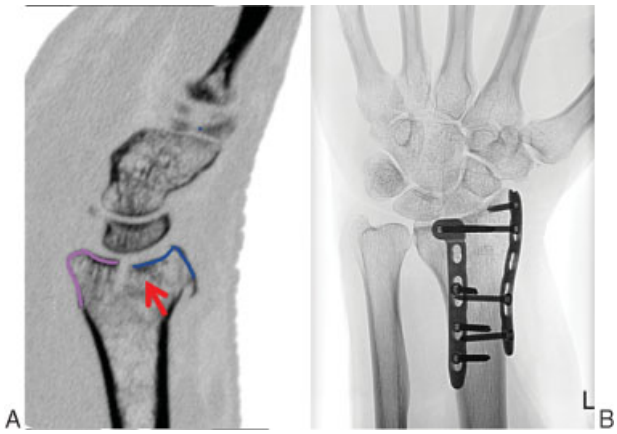

Fig. 6 Intra-articular fracture in which the lunate is in line with the dorsal corner (key corner) and subluxated from the volar corner. Therefore, a dorsal approach and fixation are preferred.

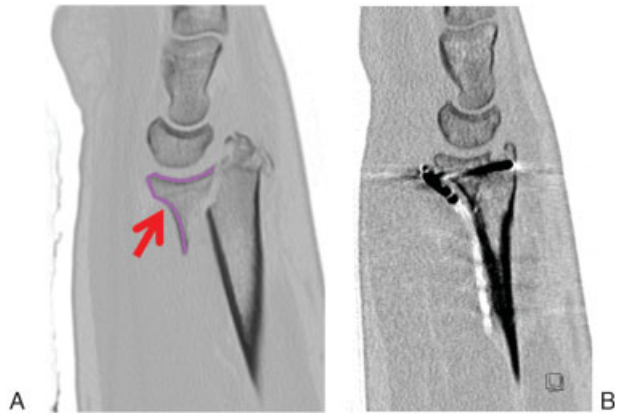

Fig. 8 Classic shear-type fracture. The lunate stays in contact with the volar corner (key corner). Volar approach with reduction and plate fixation of the volar corner restores alignment of the carpus in relation to the radial shaft.

the corners can be seen on the axial view, but displacement between the corner and the radial shaft and the carpal subluxation can only be judged on the reformatted views.

The axial view shows the relation between the volar/dorsal corner and its relation with the ulnar corner. If the volar corner is not displaced in relation to the ulna (►**Fig. 7A**), the shaft of the radius needs to be realigned with this fragment first and afterward the dorsal corner should be reduced in the direction of the volar corner. If the volar corner is displaced in relation to the ulnar corner, this fragment should be reduced (by a volar peri-FCR approach). In the sagittal view a volar subluxation of the lunate is part of the fracture configuration (►**Fig. 8**).

The presence of metaphyseal comminution (especially on the volar side) is a sign of instability, which needs to be addressed and needs proper reduction and adequate fixation and is an independent factor concerning treatment strategy. In most cases the use of longer plates makes it possible to bridge the metaphyseal area and regain enough stability for functional after treatment.

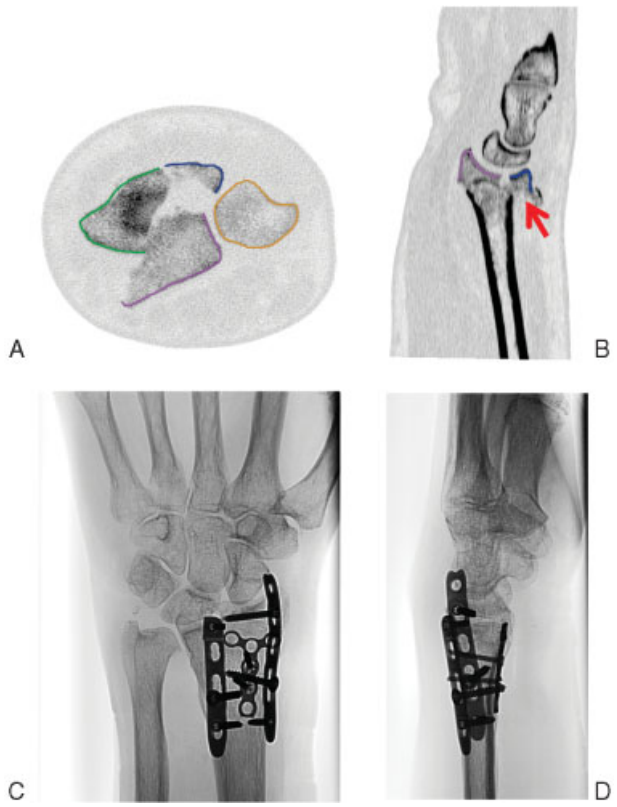

Fig. 7 Intra-articular fracture in which both corners are involved. No key corner could be identified, but both fragments are substantial, indicated by sandwich plating.

Conflict of Interest

P.R.G. Brink is a consultant for Synthes GmbH, concerning the distal radius. D. A. Rikli is a consultant for DePuySynthes.

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